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Design for a

Reinforced Concrete Armory

Architectural Engineering

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DESIGN FOR A
REINFORCED CONCRETE ARMORY

BY

PERRY WESTON SWERN

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

ARCHITECTURAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1911
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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Perry Weston Swern

ENTITLED Design for a Reinforced Concrete Armory

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

Architectural Engineering

James M White
Instructor in Charge

APPROVED: Frederick M. Mann

HEAD OF DEPARTMENT OF Architecture

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DESIGN FOR A REINFORCED CONCRETE ARMORY.

DESCRIPTION OF PLAN.

The drill floor is large enough to allow a regiment of four battalions, four companies each to form in a line of masses. The equipment rooms are located around the drill floor and accommodate the "arms" of each platoon, and from each equipment room a four foot stairway leads to the basement and enters directly into one of a series of toilet and locker rooms provided for each of the platoons. These locker and toilet rooms are fitted with full length steel lockers, one for each person, closets, urinals, showers and wash basins. The central part of the basement is arranged in connection with the two front ten-foot stairways to be used as a large banquet hall, the toilets under the administration section being used for such affairs. Directly in rear of the banquet hall is a large kitchen with its store rooms and service entrance from the rear stairways.

At drill times when there are a large number of the showers working at once the exhaust fans will serve to draw out the moisture and thus keep the rooms well ventilated and dry, this air is expelled through ducts to the roof line. The heating apparatus is under the administration section and consists of two large draw through fans which force enough heated air into the various rooms for ventilation purposes. Long coils of pipes directly under the clere-story windows furnish most of the heat to the drill room.

At each end of the building is a large cantilever balcony which has a seating capacity of 1400. Each balcony has two eight-

foot stairways which open into the end vestibules, thus allowing no spectators on the drill floor qhile they are arriving or leaving. A box office is located in each vestibule and the stairs are so arranged as to allow two ushers to take tickets quickly and easily. The interior side walls are equipped with boxes between the piers, each box accomodating twenty persons. Four, four foot stairways lead to these boxes. The total seating capacity of the balcony floor is about 3600 people, and on large occasions temporary chairs could be placed in the equipment rooms and thus increase the total capacity to about 5000 spectators, and still leave the entire drill floor to the performers. The balcony is equipped with four toilet rooms to be used by the spectators and easily accessible by them.

On each side of the balcony floor along the outside walls are two shooting tubes, one 12'-0" x 12'-0" for moving targets and one 8'-0" x 12'-0" for fixed targets. The range is 130 yards long and with the sand butts a regular system of target practice can be installed. In rear of the shooting line are accommodations for about 50 spectators.

The administration section which is in front of the main building has offices for the Commandant and his clerks, with a private toilet, a recitation room and various store rooms. On the second floor are six recitation rooms served by two five foot stairways from the front vestibule. On the first floor in the corners of the building are four company recitation rooms equipped with blackboards and maps for the explanation of various movements. The drill floor is amply lighted by means of the large glass areas at each end and a row of clere-story windows 6 feet high along the side walls just above the roof of the balcony floor.

These windows are hidden from the exterior view on account of the walls extending above the roof line of the balcony. The equipment rooms receive their light from the exterior windows. The second floor of the adimistration section is lighted by skylights and a court, this court also gives light to the front vestibule by means of five skylights.

The artificial lighting is by fixtures of three light clusters located in the various rooms. The drill floor is lighted by a series of flaming arc lights one on each pier placed high enough to be out of the direct line of sight of the people seated in the boxes. The basement being used only at periods is artificially lighted throughout no attempt being made to receive daylight through the wall windows which are more for the purpose of ventilation than lighting.

MATERIALS AND CONSTRUCTION.

The entire building is to be constructed of monolithic concrete, steel reinforcement being used wherever tension stresses occur. The floor slabs, balcony cantilevers and arch ribs are all to be cast in place. The footings are to be poured and allowed to set, the walls up to the first floor level are to be poured, and after setting the first floor with the basement stairs will be put in place, the outside walls, balcony, floor, cantilevers and stairs will be placed and the footings will be allowed to settle under these loads, the centering for the arch ribs will then be placed and the ribs poured, after setting the roof slabs will be poured their centering being supported by the rib centering.

The basement floor will consist of a six inch cinder filling with three inches of concrete cobered with one inch of cement specially prepared to give a wearing surface by using coarse crushed granite, portland cement and sand in the following proportions; one part cement, one part granite and one part sand. The floor under the shower baths and out to the bearing walls is to be of white tile laid in cement mortar and slopped so as to drain into the traps of each shower. Special tiles shaped so as to form a curve with the floor will be used as a base for all of the white marble shower partitions.

The drill floor including the equipment rooms is to be four inch slab with two inches of concrete with 2" x 4" bevelled screeds sixteen inches on centers imbedded, this is covered with a 1,1/8 inch narrow maple flooring. All floors in the administration section except the vestibule will be of the same construction except the use of 7/8 inch top flooring. The floor in the vestibules is to be tile laid in cement. The balcony will have a cement floor

throughout.

With the exception of the interior of the administsation section all walls, piers, and the under side of slabs and beams will be left as cast by the forms, this will necessitate care in making the forms and placing the concrete to see that a smooth surface of neat cement forms the outside coating. The surface is to be wire brushed to remove all board lines produced by the forms. The interior of the offices and class rooms will be given two coats of hard plaster. The trim will be hard pine painted a color to match the general tone of the concrete, excepting in the administration section which will be oak filled and varnished.

The roof is composed of a four inch slab of cinder concrete covered with a layer of prepared roofing felt, having a fine gravel coating, laid in hot asphalt. The slabs are to be cast after the arches have set and a one half inch vertical crack is to be left at each end of the slab. After the slabs have set and the forms have been removed this crack is to be caulked with oakum to within one-half inch of the top, the remainder is to be filled with asphalt at the time of laying the roof covering which is to extend over the ribs as well as the slabs.

·DESIGN·OF·FLOOR·SLABS·

·CENTER·FLOOR·SLAB·

·TYPICAL·

Span, 5'-0", Considered continuous over beam, using $M = \frac{WL^2}{12}$
W = Load per sq. ft., L = span in feet.

Loads:

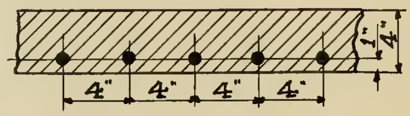
Live Load = 150 lbs./ft²
Impact = 100 lbs./ft²
Dead Load = 125 lbs./ft²
Total = 375 lbs./ft²

Allowable compression in concrete = 500 lbs/in²

Allowable stress in steel = 16,000 lbs./in²

External moment = $\frac{375 \times 5^2}{12}$ = 780 lbs. ft.

Thickness of slab 4"



4" − 1" (fireproofing) = 3" Effective depth

$.85 \times 3 = 2.55"$ arm of resisting couple

$.45 \times 3 = 1.35"$ from top of slab to neutral axis.

$\frac{500 \times 1.35 \times 12}{2}$ = 4050 lbs. stress in concrete

$\frac{4050 \times 2.55}{12}$ = 860 lbs. ft internal moment (Max.)

$\frac{4050}{16000}$ = .253 sq. in. of steel per foot of width.

Use $\frac{5}{16}$" round rods 4" on centers.

·EQUIPMENT·ROOM·FLOOR·SLAB·

·TYPICAL·

Span 5'-0"

Thickness of slap 4"

Loads:

Live Load = 150 lbs/ft²
Impact = 75 lbs/ft²
Dead Load = 125 lbs/ft²
Total = 350 lbs/ft²

$\frac{350 \times 5^2}{12}$ = 730 lbs. ft. External Moment.

$.85 \times 3 = 2.55$ arm of resisting couple

$.45 \times 3 = 1.35$ from top of slap to neutral axis

$\frac{500 \times 1.35 \times 12}{2}$ = 4050 Compression carried by concrete

$\frac{4050 \times 2.55}{12}$ = 860 lbs. ft. internal moment.

Use $\frac{5}{16}$" round rods $4\frac{1}{2}$" on centers.

·GALLERY·FLOOR·SLAB·

·TYPICAL·

·Span 7'-0" Thickness of slab $3\frac{1}{2}$"

Loads: Live Load = 40 lbs/ft²
Dead Load = 100 lbs/ft²
Total = 140 lbs./ft²

$\frac{140 \times 7^2}{12} = 572$ lbs. ft. External moment.

$3\frac{1}{2}" - 1"$ (Fireproofing) = 2.5 in. effective depth.
$.85 \times 2.5 = 2.12$ in. arm of resisting couple.
$.45 \times 2.5 = 1.13$ in. neutral axis below top of slab.

$\frac{500 \times 1.13 \times 12}{2} = 3480$ lbs. compression in concrete

$\frac{3480 \times 2.12}{12} = 716$ lbs. ft. internal moment (max.)

$\frac{3480}{16000} = .218$ sq. in. of steel req. per ft. of width.

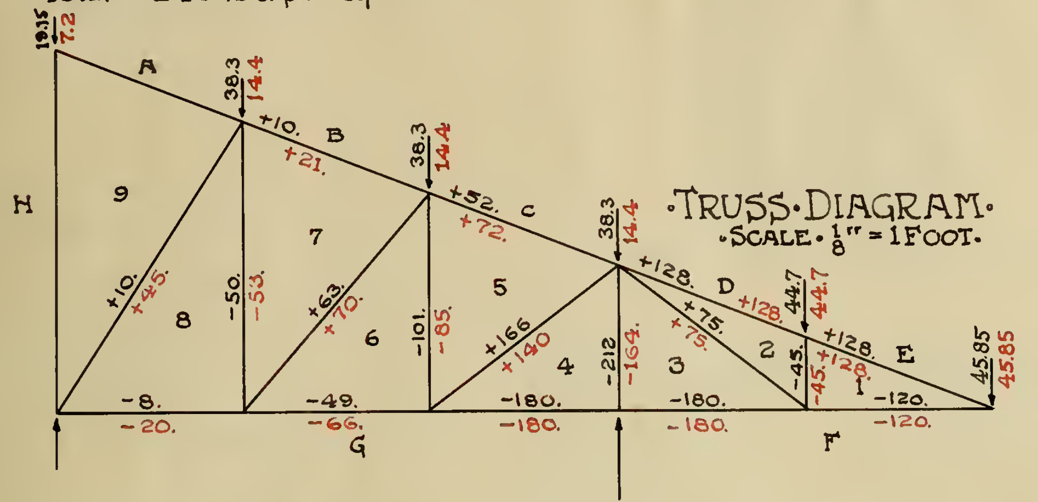
Use $\frac{3}{8}$" round rods 6" on centers.

· DESIGN · OF · BALCONY · TRUSSES ·

Live Load 150 lbs. per sq. ft.
Dead Load 90 " " " "
Total 240 lbs. per sq. ft.

Trusses 21'-0" on centers

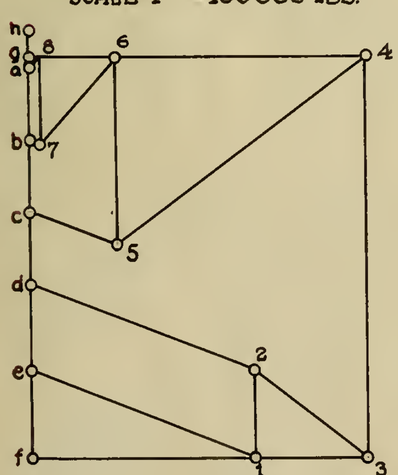
· TRUSS · DIAGRAM ·
· SCALE · $\frac{1}{8}$" = 1 FOOT ·



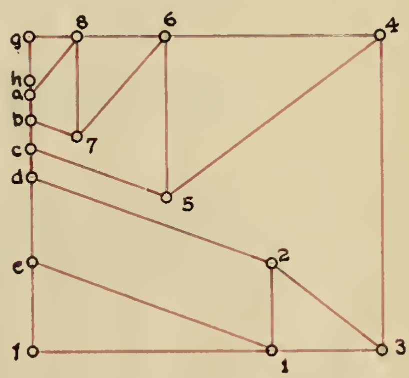
· LOADS ·

$$H\text{-}A = 240 \times \frac{7.6}{2} \times 21 = 19{,}150 \text{ lbs.}$$
$$A\text{-}B = 240 \times 7.6 \times 21 = 38{,}300 \text{ lbs.}$$
$$B\text{-}C = 240 \times 7.6 \times 21 = 38{,}300 \text{ lbs.}$$
$$C\text{-}D = 240 \times 7.6 \times 21 = 38{,}300 \text{ lbs.}$$
$$D\text{-}E = 240 \times 7.6 \times 21 + 40 \times 7.6 \times 21 = 44{,}700 \text{ lbs.}$$
$$E\text{-}F = 240 \times 7.8 \times 21 + 40 \times 7.8 \times 21 = 45{,}850 \text{ lbs.}$$

STRESS DIAGRAM
MAX · LOAD ON TRUSS
SCALE 1" = 100000 LBS.



STRESS DIAGRAM
CANILEVER LOADED ONLY
SCALE · 1" = 100,000 LBS.



·DESIGN·OF·MEMBERS·OF·BALCONY·TRUSSES·

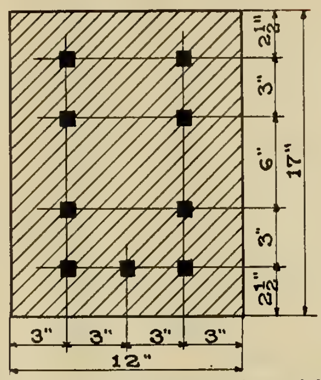
Top chord, cantilever section

Max. Stress = + 128,000 lbs.

Steel required:

$\frac{128{,}000}{16{,}000} = 8$ sq. in.

Use 9 - 1" Square rods.



·TOP·CHORD·CANILEVER·SECTION·

Top chord, section C-5

Max. Stress + 72,000 lbs.

Steel required:

$\frac{72{,}000}{16{,}000} = 4.5$ Sq. in.

Use 5 - 1" square rods.

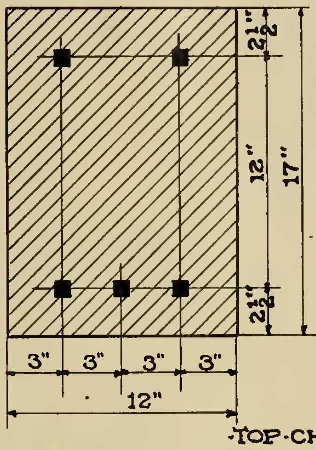
Top chord, section B-7

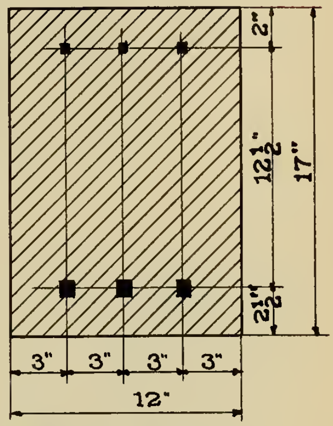
Max. Stress + 21,000 lbs.

Steel required:

$\frac{21{,}000}{16{,}000} = 1.3$ Sq. in.

Use 2 - 1" sq. rods.





·TOP·CHORD·

·SECTION·C-5· ·SECTIONS·B-7·A-9

Top chord, Section A-9

No stress due to truss action, designed as simple beam.

Load $240 \times 7.6 \times 21 = 38{,}300$ lbs.

Mom. $\frac{WL}{8} = \frac{38{,}300 \times 7.6}{8} = 36{,}400$ lbs. ft. (external moment)

$(17" - 2\frac{1}{2}") \cdot .85 = 12.3"$ effective depth.

$(17" - 2\frac{1}{2}") \cdot .45 = 6.53"$ neutral axis below compressive face.

$\frac{12 \times 6.53 \times 500}{2} = 19{,}600$ lbs. stress carried by concrete.

$\frac{19{,}600 \times 12.3}{12} = 20{,}100$ lbs. ft. internal moment of concrete.

Therefore compression steel will be required.

$36{,}400 - 20{,}100 = 16{,}000$ lbs. ft. to be carried by steel.

$\frac{16{,}300 \times 12}{12.3} = 15{,}900$ lbs.

$\frac{15{,}900}{16{,}000} = .995$ Sq. in. of compressive steel required.

Use 3 - $\frac{3}{4}$" sq. rods. (compression steel)

$\frac{36{,}400 \times 12}{12.3} = 35{,}500$ lbs. Tension

$\frac{35{,}500}{16{,}000} = 2.22$ Sq. in required area.

Use 3 - 1" sq. rods. (tension steel)

· Bottom chord ·

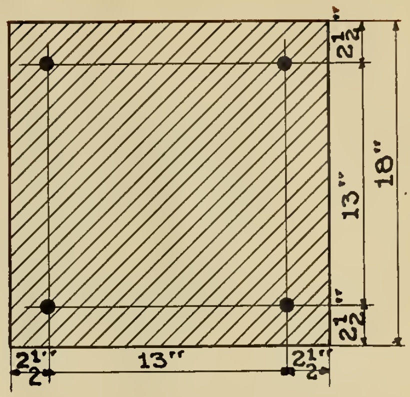
Max. stress $-120{,}000$ lbs.

$\frac{120{,}000}{500} = 240$ Sq.in. of concrete required

$\frac{240}{18} = 14$ in. req. depth

Make entire chord, 18"×18" no steel except temperature steel

Use 4 - ½" sq. rods.

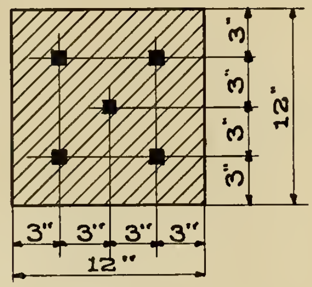


·Member · 2-3 ·

Max. stress $+75{,}000$ lbs.

$\frac{75000}{16000} = 4.7$ Sq. in. of steel req.

Use 5-1" Square rods.



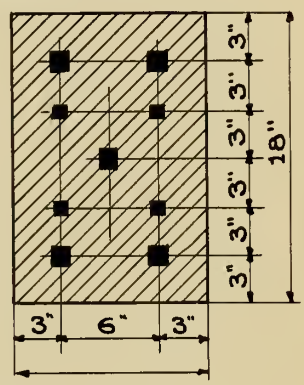
· Member · 4-5 ·

Max. stress $+166{,}000$ lbs.

$\frac{166{,}000}{16{,}000} = 10.4$ sq. in area of steel required

Use 4 -1" Sq. rods.

" $5-1\frac{3}{16}$" Sq. rods.



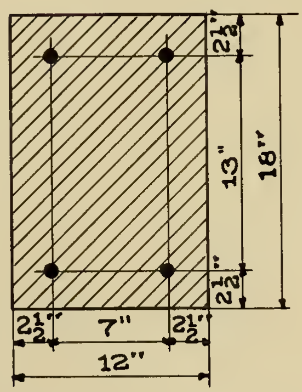
· Member · 5-6 ·

Max. Stress $-101{,}000$ lbs.

$\frac{101{,}000}{500} = 202$ Sq. in. of concrete required.

$\frac{202}{12} = 17$ in.

Use 12"×18" Member



· Member · 6-7 ·

Max. stress $+70{,}000$ lbs.

$\frac{70{,}000}{16{,}000} = 4.4$ Sq. in. of steel

Use 5-1" square rods.

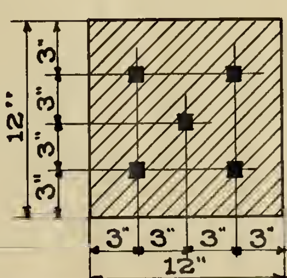
·Member · 7-8 ·

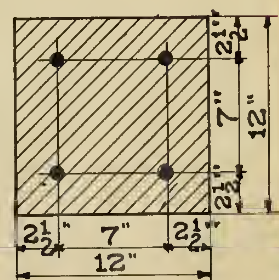
Max stress $-53{,}000$ lbs.

$\frac{53{,}000}{500} = 106$ Sq. in of concrete

$\frac{106}{12} = 8.4$ in.

Use 12"×12" member



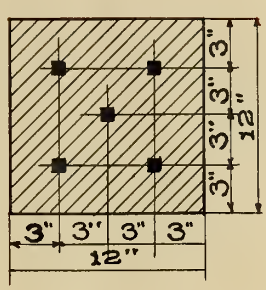


·Member· 8-9·

Max. stress +45,000 lbs.

$\frac{45000}{16000}$ = 2.8 sq.in. steel required

Use 5-$\frac{3}{4}$" square rods.



·Member· 3-4·

Max. stress −212,000 lbs.

$\frac{212{,}000}{500}$ = 425 Sq.in. of concrete

$\frac{425}{12}$ = 36.5 in.

Use 12"× 38" member